Phytoplankton Blooms in Esquimalt Lagoon in 2008, and the Effects of Freshwater Inputs

Report for the Esquimalt Lagoon Stewardship Initiative, Capital Regional District
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Photographs courtesy of Arnold Rossander

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Summary

Esquimalt Lagoon has been reported to have recurring thick phytoplankton blooms (discoloured, usually reddish water) in the past few years. Fish kills have also been reported. Although the phytoplankton blooms of Esquimalt Lagoon were studied in the 1970s and 1980s, little research has been done on them in the last twenty years. A three-month study was instituted to attempt to discover what species of phytoplankton were causing the blooms, and to investigate the influence of nutrient levels and other factors in the fresh water inputs. Phytoplankton blooms and environmental parameters, including nitrate and phosphorus levels, were monitored in Esquimalt Lagoon and its freshwater sources from early August to early October in 2008.

High concentrations of phytoplankton were seen in samples from this entire period, and in some cases plankton blooms were extremely thick. Dominant species were dinoflagellates: a small *Gymnodinium* species in August and early September, and *Prorocentrum micans* and *Prorocentrum minimum* in September and October. These are common dinoflagellate species, and were seen blooming in other places on the west coast of Vancouver Island at the same time. The small *Gymnodinium* species is probably the same species that bloomed in Esquimalt Lagoon in the 1970s and 1980s, but *Gymnodinium sanguineum*, which was the dominant bloom species during that time, was only seen in a few samples this year, at very low levels.

Nitrate levels measured in the freshwater inputs in 2008 were very high, and in the lagoon they were higher than usual in marine systems. Nitrate is considered to limit phytoplankton growth in estuarine and marine systems; phosphorus is usually the limiting nutrient in fresh water environments. Nitrate levels in the lagoon and the creeks were much lower in the 1970s and 1980s. The major sources of nitrogen into estuaries are fertilizer (from lawns, farms, and golf courses), wastewater, and atmospheric deposition.

A fish kill event occurred on September 19 and 20; this was almost certainly caused by a combination of a thick phytoplankton bloom and low tides in the middle of the night. Phytoplankton, in the process of photosynthesis, produce oxygen during the day, but use it up overnight in cell respiration. When there is a thick bloom and decreased water volume (i.e. low tide) in the middle of the night, oxygen levels in the water may fall to zero, and all life in that area (fish, other aquatic species) suffocates. There are certain species of phytoplankton that are toxic or otherwise harmful to fish and/or invertebrates, but these species were not seen in any significant concentration in Esquimalt Lagoon during the monitoring season.

Although phytoplankton productivity drives our rich marine environment in BC, continued thick phytoplankton blooms are an issue because of the threat they pose to other marine life, either by oxygen depletion or by outright toxicity. The thick accumulations of blooms have also been reported to cause problems by shading eelgrass beds, which negatively impacts the health of these important environments.

Because of the limited circulation and exchange with outside waters in Esquimalt Lagoon, high nitrate levels in the freshwater inputs and the lagoon are of extreme concern. Recommendations include:

- an investigation into nitrate sources, and better management of nitrate inputs into creeks in the Esquimalt Lagoon catchment area
- continued monitoring of phytoplankton blooms and environmental parameters in the Esquimalt Lagoon system.

Introduction

Esquimalt Lagoon is a tidal lagoon on the south end of Vancouver Island, British Columbia, close to the city of Victoria. It measures approximately 2 km long by 0.8 km wide, and has a maximum depth of about 3.5 m. The lagoon has a narrow shallow inlet at the northeast end where tidal exchange with the waters from Juan de Fuca Strait takes place.

Phytoplankton blooms are frequently observed in Esquimalt Lagoon. These blooms are usually reddish in colour and may be patchy, with thicker accumulations, and occasionally different colours of bloom, in different parts of the lagoon. Reports on the phytoplankton blooms of Esquimalt Lagoon in the 1970s and 1980s have been published (Watanabe & Robinson 1979; Robinson & Brown 1983; Voltolina & Robinson 1984; Voltolina et al. 1983; Robinson & Brown 1991, Waters et al. 1992), but little research on this issue has been done in the past 20 years.

Local residents have reported that in the last few years the blooms occurring in Esquimalt Lagoon appear to be changing. As well as the usual reddish blooms, in 2007 a chalky blue-green bloom was seen in the lagoon. Mortalities of fish and invertebrates have also been observed. This begs the questions: Are the environmental conditions in Esquimalt Lagoon worsening? Could this be influenced by nutrient inputs into the lagoon from the surrounding area?

The formation of phytoplankton blooms is primarily influenced by water temperature, stability of the water column, and nutrient concentrations. In estuarine and coastal environments nitrogen is usually the limiting nutrient; in fresh water systems it is generally phosphorus. In Esquimalt Lagoon nitrogen levels have in the past been positively correlated with phytoplankton blooms, in particular blooms of the dinoflagellate *Gymnodinium sanguineum* (Robinson & Brown 1983).

Mortalities due to phytoplankton blooms may be caused by actual toxicity of the algae to fish and/or invertebrates (e.g. the alga *Heterosigma akashiwo*, which frequently causes mortalities in finfish aquaculture operations in BC), or by causing low oxygen conditions. Overnight respiration of thick phytoplankton blooms, or bacterial respiration on the breakdown of a bloom, can use up all of the available dissolved oxygen in the water; fish and invertebrates, which also need dissolved oxygen for their respiration, then die.

There are five main streams and outfalls, radiating from the southwest to the north side, which feed into Esquimalt Lagoon. Dependant on rainfall, these bring varying amounts of fresh water and nutrients into the lagoon. Salt water enters the lagoon from the inlet on the northeast end of the lagoon. Water exchange is judged to be approximately 35% of the low-water volume of the lagoon per tidal cycle (Scrimger 1960).

The lagoon is shallow, with a maximum depth of ~3.5 m, so water temperatures heat up quickly with fine weather in the summer, and in the winter it becomes colder than the waters of Juan de Fuca Strait outside the lagoon.

Studies have shown that in the centre of the lagoon, away from the turbulent effects of the inlet, in the summer the water column is generally in three layers, with a surface layer of high temperature, lower salinity water influenced strongly by the freshwater inputs, and a bottom layer of cooler more saline water from the tidal input (Juan de Fuca water), with an intermediate layer between (Voltolina et al. 1985). This stratification may occasionally break down in windy conditions (Robinson & Brown 1983). Flow direction in the layers varies with the tides. In mid-lagoon with outgoing tide the flow is greatest in the surface and deep water, with little movement in the intermediate layer; the incoming tide flow is also mostly seen at the surface, with a reverse flow in the bottom and intermediate layers (Scrimger 1960).

Sampling and Analysis

Samples were taken from Esquimalt Lagoon on four dates in 2008, from August 5 to October 8. Four sites in the lagoon, and five outlet sites, were sampled (Fig. 1).

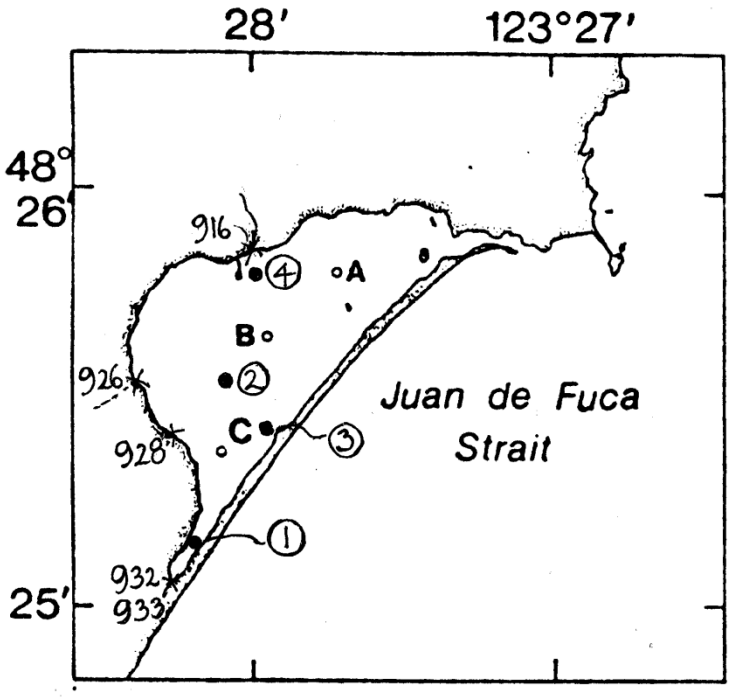

Figure 1: Sampling sites in Esquimalt Lagoon. Sites 1-4 are phytoplankton sampling sites; sites 916-933 are outfall sampling sites. A, B, C, are historical sampling sites of Robinson, Brown, and Voltolina.

Discrete water samples (100 mL) were taken from a depth of 0.3m at the lagoon sites and preserved with Lugol's iodine for phytoplankton analysis. Dissolved oxygen, pH, temperature, turbidity, fecal coliform, phosphorus, and nitrate were measured at all sites; salinity was measured at the

phytoplankton sites only, and conductivity and flow rate were measured at the outlet sites. HACH kits were used to measure nitrate and phosphorus at the lagoon stations in the field; nitrate and phosphorus and fecal coliform in the lab were measured as in the "B.C. Environmental Laboratory Manual for Analysis of Water, Wastewater, Sediment and Biological Materials" (2005 Edition) and "Standard Methods for Examination of Water and Wastewater", 21st Edition. A YSI 556 MPS Multimeter was used to measure the other environmental parameters.

Samples were taken August 5, September 3, September 19, and October 8. Mortalities (dead fish and crabs) were observed early in the morning on September 19 and 20.

Phytoplankton samples were analysed by Nicky Haigh at Vancouver Island University (email: Nicky.Haigh@viu.ca). One-mL aliquots were examined in a Sedgewick Rafter slide using a Leitz Laborlux compound microscope, and phytoplankton species were identified to the lowest practicable taxonomic level. Dominant species, and any species known or suspected to be harmful to fish or invertebrates, were noted and counted. Total phytoplankton biomass was approximated on a scale of 1 (very low) to 5 (very high). Percent biomass in five major groups (diatoms, dinoflagellates, raphidophytes, other flagellates, and microzooplankton) was also approximated.

Results and Discussion

Phytoplankton

Dinoflagellate species were dominant at bloom concentrations in all Esquimalt Lagoon phytoplankton samples taken in 2008. The dominant species were a small gymnodinioid dinoflagellate, tentatively identified as *Gyrodinium estuariale,* and *Prorocentrum micans* and *Prorocentrum minimum* (Fig. 2).

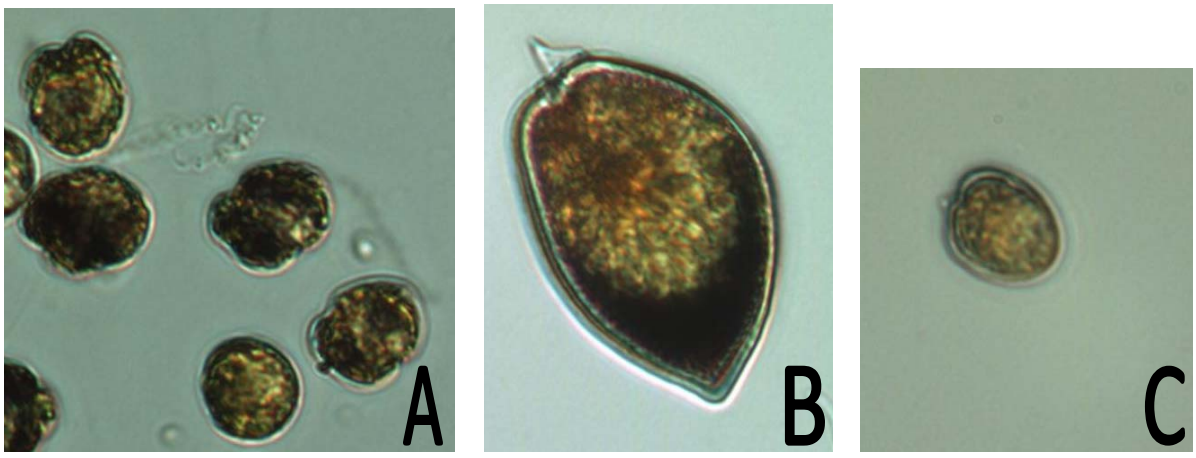

Figure 2: Dominant dinoflagellate species in Esquimalt Lagoon August – October 2008. A. *Gyrodinium estuariale* (tentative identification). B. *Prorocentrum micans*. C. *Prorocentrum minimum*. Photographs taken from Lugol's iodine preserved Esquimalt Lagoon samples, all species to the same scale.

Table 1 shows dominant species name and cell count, total biomass, and biomass percent constituent for all dates and sites sampled. In addition, the presence of *Gymnodinium sanguineum* is noted. This dinoflagellate species was reported to be the dominant alga in most blooms in Esquimalt Lagoon from

1976 to 1982 (Robinson & Brown 1983). This year it was seen in the August and September samples, but not in October, and it was not present at all sites, nor were concentrations of this species very high.

Table 1: Phytoplankton in August-October 2008 Esquimalt Lagoon samples. "Biomass" is total phytoplankton biomass approximated in a scale of 1.0 (very low) to 5.0 (very high). "% Constituent" is approximate percent of total phytoplankton biomass in five constituent groups: diatoms (DT), dinoflagellates (DF), raphidophytes (R), other flagellates (OF), and microzooplankton (MZ). "GYM SANG." notes the presence (+) of the dinoflagellate *Gymnodinium sanguineum* in the sample.

DATE	SITE	DOMINANT SPECIES		BIOMASS	% CONSTITUENT					GYM SANG.
		NAME	CELLS/ML		DT	DF	R	OF	MZ	
5 Aug	1	*Gyrodinium estuariale*	68,000	5.0	14	85	0	0	1	
	2	*Gyrodinium estuariale*	2200	4.0	1	90	0	1	8	+
	3	*Gyrodinium estuariale*	11,000	4.5	4	92	0	1	3	+
	4	*Gyrodinium estuariale*	80,000	5.0	1	98	0	0	1	+
3 Sep	1	*Prorocentrum minimum*	~800	4.5	5	90	0	1	4	
	2	*Gyrodinium estuariale*	11,000	5.0	0	99	0	0	1	+
	3	*Gyrodinium estuariale*	3600	4.5	4	88	0	1	7	
	4	*Gyrodinium estuariale*	300,000	5.0	0	100	0	0	0	+
19 Sep	1	*Prorocentrum micans*	6300	4.5	2	98	0	0	0	+
	2	*Prorocentrum micans*	3700	4.5	0	98	0	1	1	+
	3	*Prorocentrum micans*	3300	4.5	2	97	0	0	1	
	4	*Prorocentrum micans*	5300	4.5	1	95	0	2	2	
8 Oct	1	*Prorocentrum micans*	580	4.0	4	85	0	1	10	
	2	*Prorocentrum micans*	~320	3.5	3	95	0	1	1	
	3	*Prorocentrum micans*	~420	4.0	4	85	0	1	10	
	4	*Prorocentrum micans*	9300	5.0	1	97	0	1	1	

Plankton biomass was generally high in Esquimalt Lagoon samples, and in some cases it was very high (i.e. sites 1 and 4 August 5, sites 2 and 4 September 3, and site 4 October 8). In almost all cases dominant species counts were highest at site 4; the most remarkable was in the September 3 samples, with ~300,000 cells/mL *G. estuariale* and ~15,000 cells/mL *P. micans* in the site 4 samples. These counts are an average of duplicate samples taken at this site on this date: one had 433,000 cells/mL *G. estuariale* and 11,000 cells/mL *P. micans*; the other had 200,000 cells/mL *G. estuariale* and 21,000 cells/mL *P. micans*. These samples were so thick with plankton that they had to be diluted in order to obtain an accurate count of the dominant species.

Overall, phytoplankton concentrations were very high on August and September sampling dates, and high on the October sampling date, indicating that thick phytoplankton blooms persisted for a full two months at least in 2008. In Robinson and Brown (1983), they report on the presence of "red water" from 1974 to 1982. Generally speaking, the periods of blooms seem shorter for those years, although the 1980 blooms were observed in late July and August (unidentified *Gymnodinium* sp. – "*Gymnodinium* sp. 1A") and in October (*Gymnodinium sanguineum*). However, in 1982 no blooms were seen at all. Highest cell counts of *G. sanguineum* in those years generally ranged from 750 – 3100 cells/mL, with the exception of 1981, when 11,400 cells/mL were seen at 1m in late October. Highest cell counts of

dinoflagellate species in Esquimalt Lagoon reported by Waters et al. (1992) ranged from 130 to 12,000 cells/mL. This is an order of magnitude less than what we have seen in 2008.

The dominant dinoflagellate that was seen in August and September 3 samples, tentatively identified as *Gyrodinium estuariale*, is likely the same species that was often dominant in Esquimalt Lagoon in the 1970s and 1980s when *G. sanguineum* was not. This species was referred to as *Gymnodinium* sp. 1A (LN Brown, pers. com.).

In all samples sent from Esquimalt Lagoon in 2008 dinoflagellates accounted for 85% or more of the phytoplankton biomass; generally it was greater than 90%, and in over half of the samples it was 95% or above.

Very little was seen in these samples in the way of known or suspected toxic species of phytoplankton. The only sample that contained harmful species was the one from site 1 on August 5, with ~20 cells/mL *Alexandrium* sp., and ~1 cell/mL *Dictyocha speculum*. Certain *Alexandrium* species are responsible for paralytic shellfish poisoning ("red tide") in our area, and at higher concentrations (~500 cells/mL) they have been implicated in fish kills. *Dictyocha speculum* has caused fish kills in BC at levels of ~300 cells/mL.

Nutrients

Nitrate levels at sampling stations in the lagoon ranged from non-detectable to 36 μmol/L. Lowest levels were seen on the September sampling dates, especially September 19, and highest were seen on August 5 (Fig.3). In the September samples the highest concentrations of nitrate were seen at site 1, on the southwest side of the lagoon (1.14 – 7.14 μmol/L), at the other sites levels ranged from not detectable to 0.428 μmol/L.

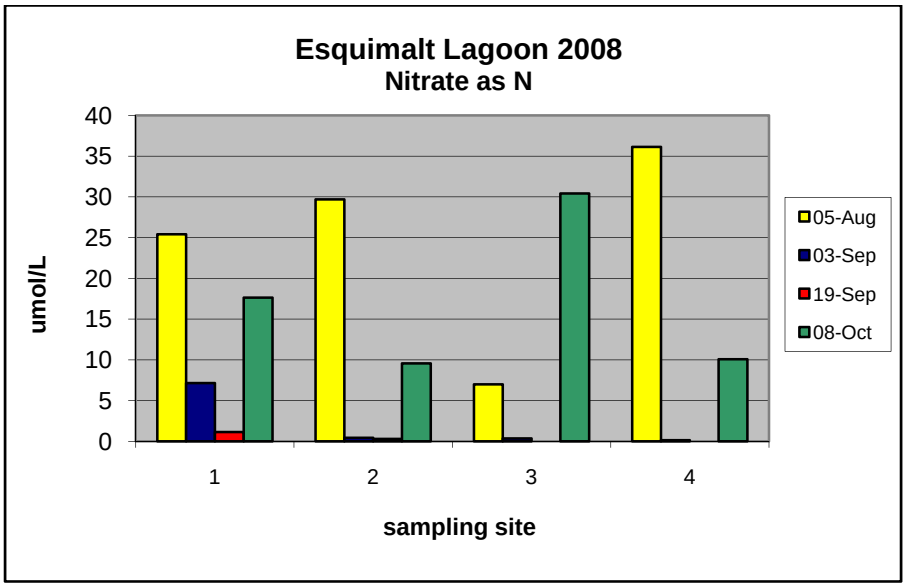

Figure 3: Nitrate concentrations at 0.3m at sites 1-4 in Esquimalt Lagoon, August to October 2008.

Nitrate levels in the freshwater inputs were generally very high (Fig. 4, note y-axis values). Highest concentrations were seen at the outfalls at sites 932 and 933, with a maximum of 593 µmol/L at 933 and 436 µmol/L at 932 on August 5. Nitrate concentrations were generally lowest at site 926 (Bee Creek), ranging from 7 – 57 µmol/L on the two days sampled there (September 3, October 8). Highest overall nitrate was seen on August 5.

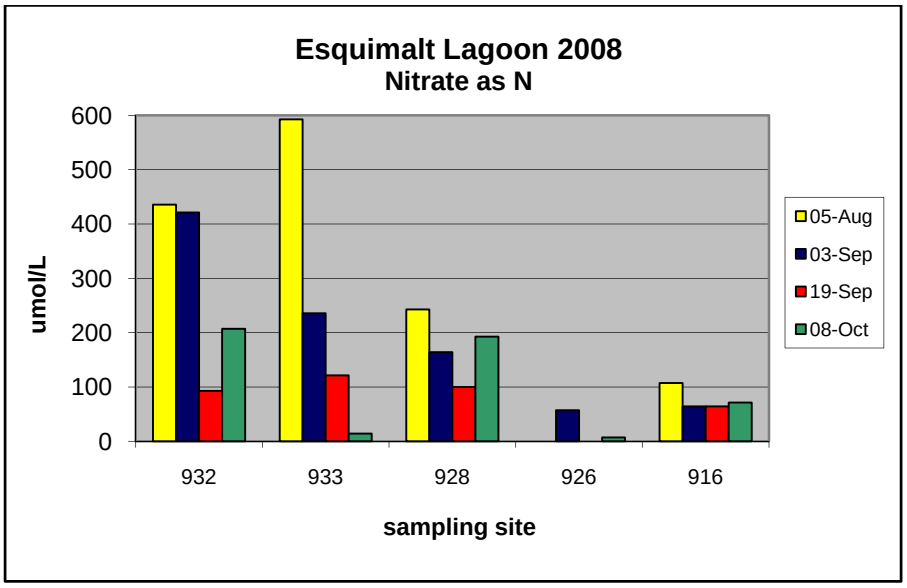

Figure 4: Nitrate levels at sites 916-933 in Esquimalt Lagoon from August to October 2008.

Historical nitrate levels (Robinson & Brown 1983) were much lower. In 1979, nitrate concentrations in streams feeding into Esquimalt Lagoon were measured between March and late June; these averaged 54 – 74 µmol/L. In the lagoon, nitrate, measured at site B (see Fig. 1) was only 1 – 15 µmol/L in late July, and was less than <1 µmol/L at all depths from late August through October.

Phosphorus levels measured in Esquimalt Lagoon this year were higher at the lagoon sites than in the freshwater inputs. Concentrations ranged from 1.4 – 13.6 µmol/L in the lagoon sites, and not detectable to 10 µmol/L in the freshwater inputs (Fig. 5). Highest phosphorus levels were seen on September 19, and are likely associated with the dead organisms in the lagoon at that time – in particular at Selleck Creek (site 928), where many dead fish were seen earlier in the morning, and phosphorus levels were measured at 10 µmol/L. Phosphorus at other input sites ranged from 0.3 – 2.9 µmol/L.

In 1979 phosphorus levels in the streams were similar to what we see today (0.15 – 2.29 µmol/L), but were lower in the lagoon, generally 0.5 – 1.5 µmol/L (Robinson & Brown 1983).

Temperature and Salinity

Water temperatures in Esquimalt Lagoon on sampling days in 2008 were warmest on August 5, and coolest on October 8 (Fig. 6). Temperatures were warmer in the lagoon sites than at the input sites in August and September, but with cooling of the lagoon in October the freshwater input temperatures were higher. The range of temperatures was greatest in the lagoon – from a high of 25.2 C on August 5

to a low of 11.2 C on October 8 at site 4. There was much less variation in the temperature of the freshwater inputs over the sampling period: the most was in Selleck Creek (site 928), which ranged from 17.9 C on August 5 to 12.7 C on October 8; the least was at site 932, where the temperature ranged from 12.0 C on August 5 to 12.2 C on October 8. Although temperatures ranged fairly widely between the lagoon sampling sites, none was consistently warmer or cooler than the others.

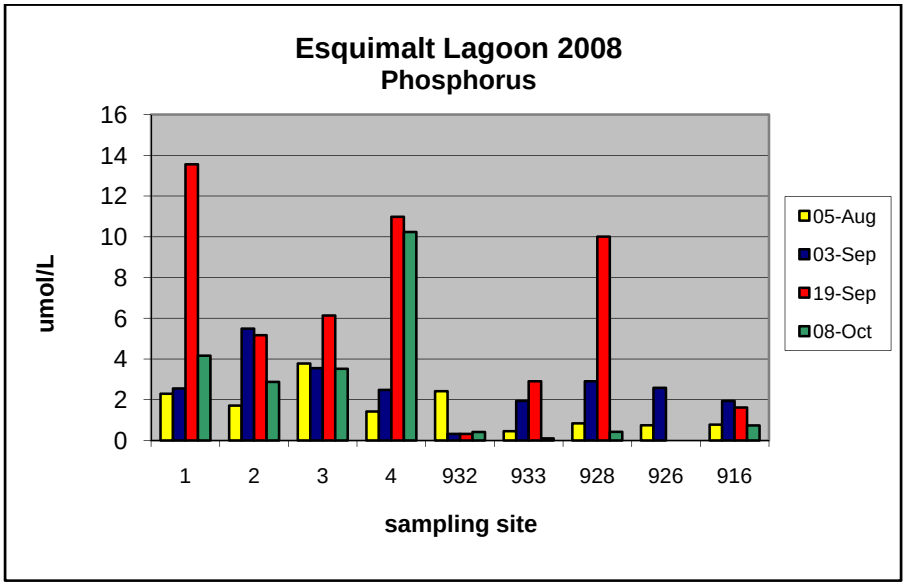

Figure 5: Phosphorus levels at 0.3m at monitoring sites in Esquimalt Lagoon from August to October 2008.

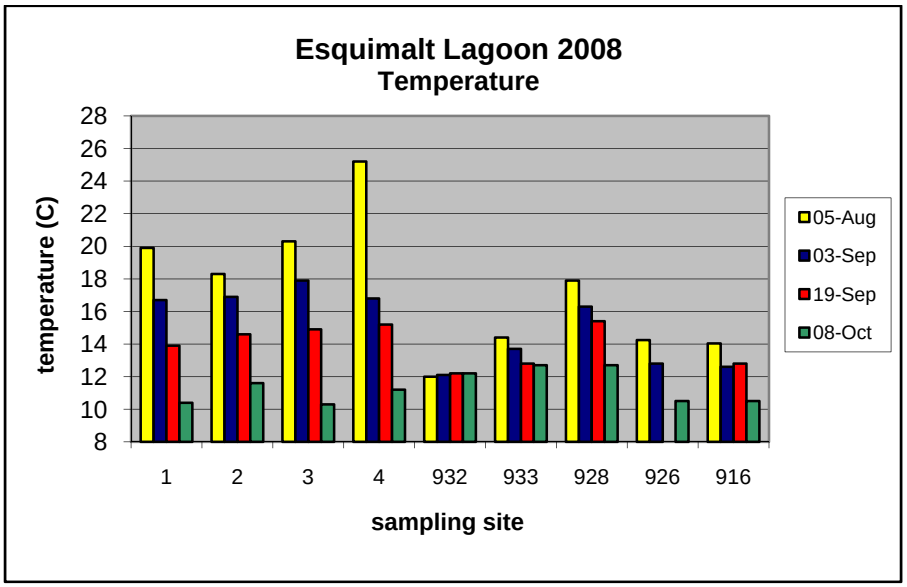

Figure 6: Water temperatures at 0.3m at sampling sites in Esquimalt Lagoon from August to October 2008.

Salinity in the lagoon sites did not vary a great deal during the sampling period, ranging only from 25.8 ppt to 30.6 ppt (Fig. 7). Average salinity was highest on August 5, and lowest on October 8. None of the sampling sites was seen to have salinity consistently higher or lower than the other sites.

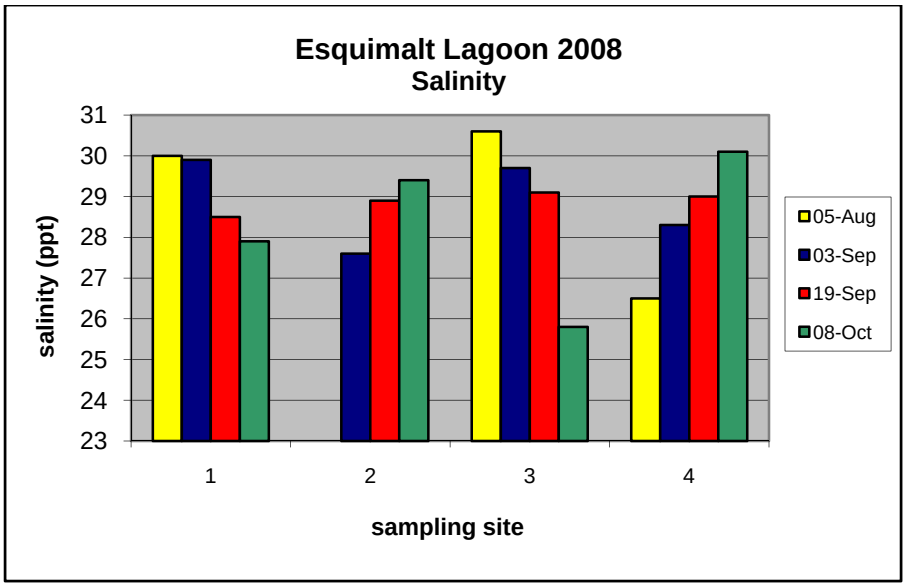

Figure 7: Salinity values at 0.3m at sampling sites 1-4 in Esquimalt Lagoon, August to October 2008.

Dissolved Oxygen and Tides

Dissolved oxygen (DO) levels in Esquimalt Lagoon were consistently high, both in the lagoon and in freshwater inputs, when sampled in 2008 (Fig. 8). In some cases DOs were actually supersaturated at the lagoon sites; this is not unusual during thick phytoplankton blooms. DOs ranged 8.2 – 19.4 mg/L at 0.3m at the lagoon sites on the sample dates, with generally lowest DOs on September 19, and highest on September 3. In the freshwater inputs DOs only ranged from 8.8 – 11.6 mg/L, with levels fairly consistent in each stream or outfall, except for site 916 (Colwood Creek) where DOs decreased steadily from 10.0 mg/L to 8.8 mg/L over the sampling period. However, 8.8 mg/L is still a moderate to high DO level.

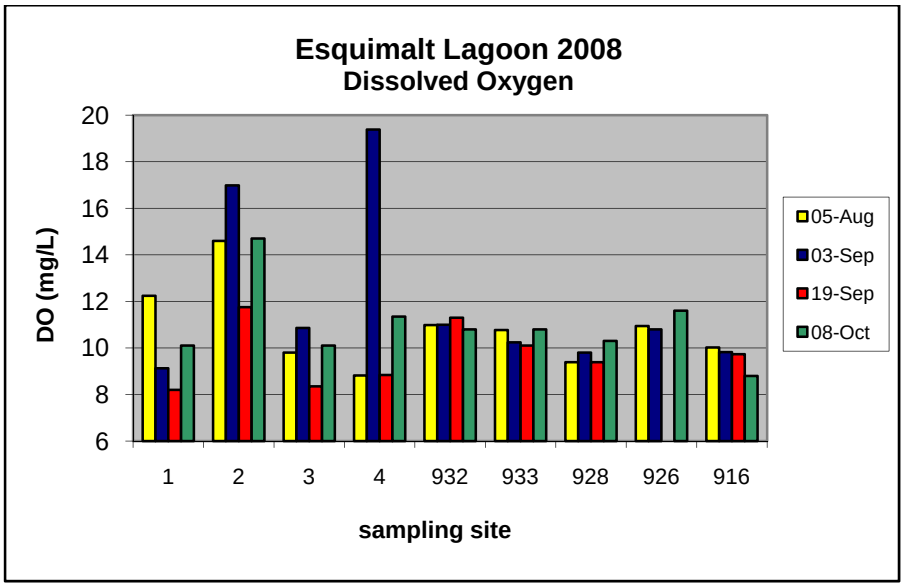

Figure 8: Dissolved oxygen levels at 0.3m at Esquimalt Lagoon sampling sites from August to October 2008.

Overnight on September 18/19 and September 19/20 there appear to have been low DO conditions. Dead fish and invertebrates were observed in the mornings of September 19 and 20. The combination of a thick phytoplankton bloom and a low tide in the middle of the night (0.7m at 12:22 AM September 19, 0.6m at 1:16 AM September 20) probably combined to produce low DOs. Phytoplankton use oxygen for respiration; if there are many of them they need more oxygen. When the tide goes out there is less water, and therefore less oxygen available, and DOs can quickly become too low for other organisms to survive. This is not a problem during the day because when there is light phytoplankton produce oxygen during photosynthesis. This is why oxygen levels become supersaturated in the day during thick phytoplankton blooms, as on September 3.

The fact that this low oxygen situation was not observed during sampling is understandable. By the time sampling was started around noon on September 19, the tide had come in, bringing oxygenated water back into the lagoon, and the phytoplankton bloom had been photosynthesizing and producing oxygen for hours. There is a signal of the event, however, with lower DOs at the shallower lagoon sampling sites (8.2 – 8.8 mg/L) in comparison to the deeper site 2, where the DO was a respectable 11.8 mg/L.

Other

Turbidity measured in Esquimalt Lagoon this season was generally higher at the lagoon sites than in the outlets and creeks, except for Selleck Creek (928), which was generally more turbid than the other freshwater inputs (3.84 – 7.71 NTU, in comparison to 0.24 – 2.39 NTU) (Fig. 9). The turbidity at the lagoon sites did not always correlate with the counts of dominant plankton or overall phytoplankton biomass, although the highest turbidity measurement of 133 NTU was seen in the thickest dinoflagellate bloom at site 4 on September 3 (~300,000 cells/mL), and the lowest (2.48 NTU) was measured at site 2 on October 8, where the phytoplankton biomass level of 3.5 was the lowest seen this sampling season.

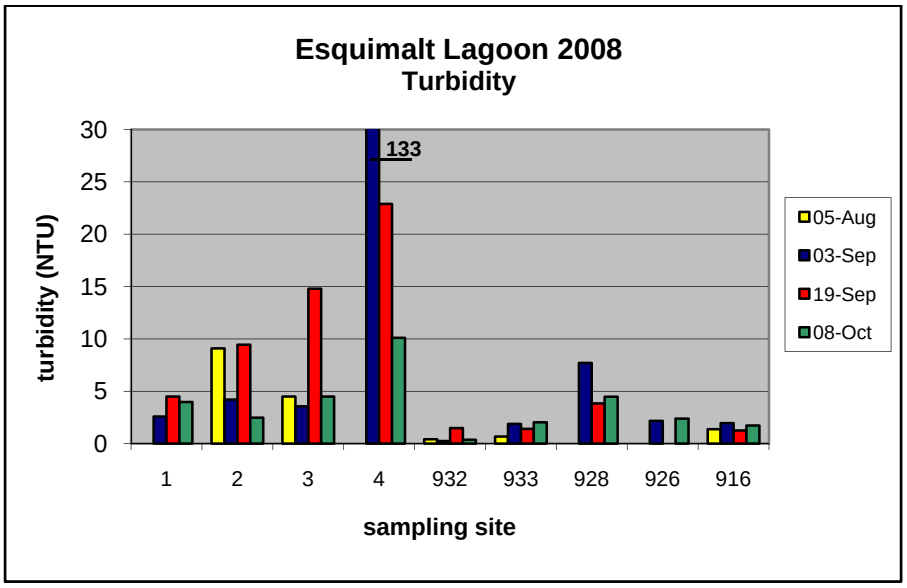

Figure 9: Turbidity measurements at 0.3m in Esquimalt Lagoon sampling sites, August to October 2008.

Measurements of pH taken this sampling season ranged from 7.7 – 8.7 in the lagoon, and 6.72 – 8.16 in the freshwater inputs (Fig. 10). Lowest outfall / creek pH values were seen at site 932 and, probably due to this input, site 1 regularly had the lowest pH of the lagoon sites.

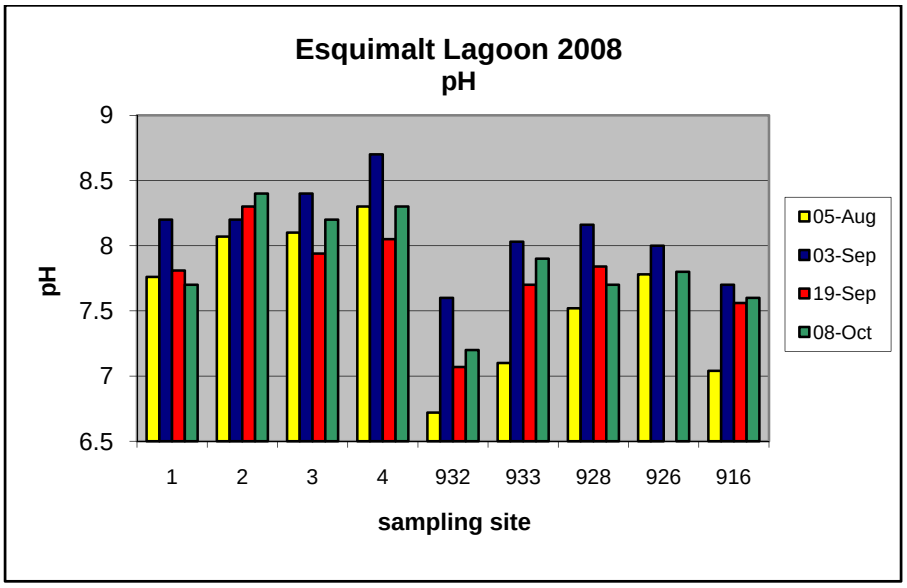

Figure 10: Values for pH at sites in Esquimalt Lagoon on sampling dates from August to October 2008.

Fecal coliforms during the sampling season were generally fairly low (<1 – 33 FC/100mL) at the lagoon sites, except for on September 19, when they ranged from 70 – 210 FC/100mL (Fig. 11). This is above the 100 FC/100mL cut-off level for body contact / recreation. Fecal coliform levels were generally elevated at all sampling sites on this date, with a high of 2500 FC/100mL at the Selleck Creek (928) site. As this is where many of the dead fish were seen on this date, this may have some relation to the high fecal coliform findings.

The fresh water inputs generally had higher fecal coliform levels than the lagoon sites, ranging mostly from <1 to 300 FC/100mL, although in two instances concentrations of 1000 FC/100mL were seen (site 933 on August 5, site 928 on October 8). Selleck Creek fecal coliform levels were always greater than 100 FC/100mL.

Watanabe and Robinson (1980) studied fecal coliform levels in Esquimalt Lagoon and its freshwater inputs from February 1979 to April 1980. They found that the fecal coliform levels were generally low in the lagoon, but extremely variable, including some extremely high measurements, in the streams. At that time there was no sewer servicing the houses in the southwest side of the lagoon, and the use of septic tanks was a large contributor to fecal coliform levels seen, especially in the western streams. They did not, however, find any correlation between fecal coliform and nitrate levels, and therefore phytoplankton blooms, and concluded that sewage did not have a significant influence on nitrate levels in the lagoon.

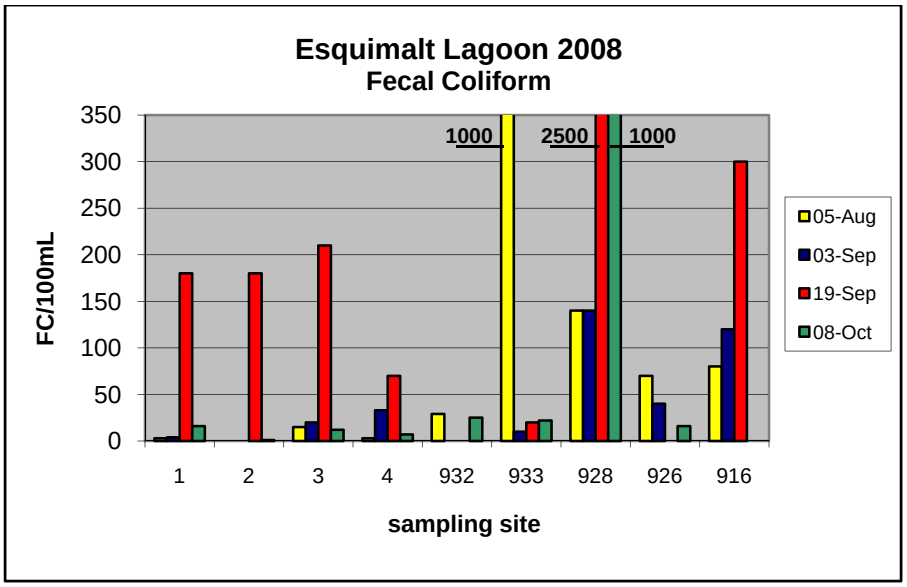

Figure 11: Fecal Coliform levels at sampling sites in Esquimalt Lagoon, August to October 2008.

Water flow was visually estimated at the freshwater inputs on the September and October sampling dates. This flow varied from 10 – 75 L/min.

Table 2: Water flow (L/min) at freshwater input sites in Esquimalt Lagoon on sampling dates in September to October 2008.

SITE	3 Sept	19 Sept	8 Oct
932	25	35	45
933	35	10	35
928	25		35
926	75		45
916	25		30

In 1980, Watanabe and Robinson measured stream flow in five freshwater inputs in the Esquimalt Lagoon catchment area, and calculated their relative importance to the lagoon environment. They found that Colwood Creek (site 916 this study) accounted for ~44% of the freshwater input, with the outlet from the fish ponds at Royal Roads (not monitored in this study) secondary at ~25%, Bee Creek (site 926) ~18%, Selleck Creek (site 928) ~7%, and the input at the southwest end of the lagoon (sites 932/933 in this study) ~5%.

Conclusions and Recommendations

The Esquimalt Lagoon system has all the conditions necessary for continuing thick phytoplankton blooms which will have negative impacts on the lagoon as a whole. Low oxygen levels due to thick blooms combined with summer low tides in the middle of the night will continue to kill fish and other aquatic life. Shading from these thick blooms may also impact the health of the eel grass beds.

High nitrate inputs from the catchment area around the lagoon feed the phytoplankton growth. Nitrate levels, both in the lagoon and the freshwater inputs, are considerably higher than in the 1970's and 80's, and phytoplankton blooms appear to be considerably thicker and more common.

When we look at the influence of the freshwater inputs we have to consider three major things: the flow of the creek or outfall, and therefore the total volume added to the lagoon; the nutrient load in that input; and the mixing of that material and its retention within the lagoon. Inputs on the eastern end of the lagoon are more likely to mix with the tidal inflow and be expelled from the lagoon. In the western side, inputs are more likely to be retained in the lagoon due to slower circulation, so even if there is less total volume from the creek, the effects on the nutrient loading of the creek may be greater.

The major sources of nitrogen into estuarine areas are fertilizers (lawns, farms, golf courses), wastewater, and atmospheric deposition (the effects of which may also be seen in runoff). The source of high nitrate in the freshwater inputs into Esquimalt Lagoon should be investigated, and in future must be better managed to improve the health of the lagoon.

This year's plankton blooms do not appear to have been unusual compared to what has been seen in Esquimalt Lagoon in the past few years. However, phytoplankton species dominance and levels can vary widely from year to year. I would recommend continuing to monitor the phytoplankton and environmental parameters, especially nitrate, in the lagoon, until an improvement is seen in this issue.

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